YELLOWFIN SOLE

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EXECUTIVE SUMMARY

The following changes have been made to this assessment relative to the November 2000 SAFE:

Changes to the input data

1) 2000 fishery age composition.
2) 2000 survey age composition.
3) 2001 trawl survey biomass point estimate and standard error.
4) Estimate of the discarded and retained portions of the 2000 catch.
5) Estimate of total catch and discard through 15 September 2001.

Assessment results

1) The projected age 2+ biomass for 2002 is 1,596,800 t.
2) The projected female spawning biomass for 2002 is 453,700 t.
3) The recommended 2002 ABC is 114,900 t based on an $F_{40\%}$ (0.11) harvest level.
4) The 2002 overfishing level is 136,400 t based on an $F_{35\%}$ (0.13) harvest level.

New Analysis

Annual estimates of survey catchability relative to bottom temperature are presented as alternative models.

SUMMARY

	2000 Assessment Recommendations for 2001 harvest	2001 Assessment Recommendations For 2002 harvest
Total biomass	2,384,180 t	1,596,800 t
ABC	176,180 t	114,900 t
Overfishing yield	208,890 t	136,400 t
F_{ABC}	$F_{0.40} = 0.11$	$F_{0.40} = 0.11$
$F_{overfishing}$	$F_{0.35} = 0.13$	$F_{0.35} = 0.13$

INTRODUCTION

The yellowfin sole (Limanda aspera) is one of the most abundant flatfish species in the eastern Bering Sea (EBS) and is the target of the largest flatfish fishery in the United States. The resource inhabits the EBS shelf and is considered one stock. Abundance in the Aleutian Islands region is negligible.

Yellowfin sole are distributed in North American waters from off British Columbia, Canada, (approx. lat. 49º N) to the Chukchi Sea (about lat. 70º N) and south along the Asian coast to about lat. 35º N off the South Korean coast in the Sea of Japan. Adults exhibit a benthic lifestyle and occupy separate winter, spawning and summertime feeding distributions on the eastern Bering Sea shelf. From over-winter grounds near the shelf margins, adults begin a migration onto the inner shelf in April or early May each year for spawning and feeding. The directed fishery typically occurs from spring through December.

CATCH HISTORY

Yellowfin sole have annually been caught with bottom trawls on the Bering Sea shelf since the fishery began in 1954. The catch locations of vessels targeting on yellowfin sole in 2000, by quarter, are shown in the Appendix figures. The total catch (t) since implementation of the MFCMA in 1977 are shown in Table 3.1.

Yellowfin sole were overexploited by foreign fisheries in 1959-62 when catches averaged 404,000 t annually (Fig. 3.1). As a result of reduced stock abundance, catches declined to an annual average of 117,800 t from 1963-71 and further declined to an annual average of 50,700 t from 1972-77. The lower yield in this latter period was partially due to the discontinuation of the U.S.S.R. fishery. In the early 1980s, after the stock condition had improved, catches again increased reaching a recent peak of over 227,000 t in 1985.

During the 1980s, there was also a major transition in the characteristics of the fishery. Yellowfin sole were traditionally taken exclusively by foreign fisheries and these fisheries continued to dominate through 1984. However, U.S. fisheries developed rapidly during the 1980s in the form of joint ventures, and during the last half of the decade began to dominate and then take all of the catch as the foreign fisheries were phased out of the EBS. Since 1990, only domestic harvesting and processing has occurred.

The 1997 catch of 181,389 t was the largest since the fishery became completely domestic which decreased to 101,201 t in 1998. The 2000 catch totaled 83,850 t and only 36,000 t were cught through September 15, 2001. The 2000 catch totaled only 44% of the ABC and 68% of the TAC. The yellowfin sole harvest in 2001 has been constrained by two seasonal closures due to the attainment of halibut PSC limits: from April 26-May 21 and from June 11-July 1.

The catch information presented above also includes large amounts of yellowfin sole discarded overboard in DAP fisheries since its beginning in 1987. Discard estimates are calculated from weekly observer discard estimates, by target fishery, applied to the weekly 'blend' estimate of retained catch from the NMFS regional office summed over the fishing year.

Year	Retained	Discards
1987	3	1
1988	7,559	2,274
1989	1,279	385
1990	10,093	4,200
1991	89,054	26,788
1992	103,989	45,580
1993	76,798	26,838
1994	107,629	36,948
1995	96,718	28,022
1996	101,324	28,334
1997	149,570	31,818
1998	80,365	20,836
1999	55,202	12,118
2000	69,788	14,062

The rate of discard has ranged from 17% of the total catch in 1997 and 2000 to 30% in 1992. Discarding occurs primarily in the yellowfin sole directed fishery, and in lesser amounts in the rock sole, flathead sole, and ‘other flatfish’ fisheries.

DATA

The data used in this assessment include estimates of total catch, bottom trawl survey biomass estimates and their attendant 95% confidence intervals, catch-at-age from the fishery and population age composition estimates from the bottom trawl survey. Weight-at-age and proportion mature-at-age are also available from studies conducted during the bottom trawl surveys.

Fishery Catch and Catch-at-Age

This assessment uses fishery catch data from 1955- September 15, 2001 (Table 3.1) and fishery catch-at-age (numbers) from 1964-2000 (Table 3.2, 1977-2000).

Survey Biomass Estimates and Population Age Composition Estimates

The survey estimates of population numbers-at-age from 1975 and 1979-2000 are used in the assessment model and are shown for 1982-2000 in Table 3.3. Biomass (t) estimates from AFSC surveys conducted in a standardized area of the EBS encompassing waters from 20 to 200 m and from the Alaska Peninsula north to a latitude of St. Matthew and Nunivak Islands are given below:

Year	Age Groups 0-6	7 plus	Total	95% confidence Interval of Total
1975	169,500	803,000	972,500	812,300 - 1,132,700
1979	211,500	1,655,000	1,866,500	1,586,000 - 2,147,100
1980	235,900	1,606,500	1,842,400	1,553,200 - 2,131,700
1981	343,200	2,051,500	2,394,700	2,072,900 - 2,716,500
1982	685,700	2,692,100	3,377,800	2,571,000 - 4,184,600
1983	198,000	3,337,300	3,535,300	2,958,100 - 4,112,400
1984	172,800	2,968,400	3,141,200	2,636,800 - 3,645,600
1985	166,200	2,277,500	2,443,700	1,563,400 - 3,324,000
1986	80,200	1,829,700	1,909,900	1,480,700 - 2,339,000
1987	125,500	2,487,600	2,613,100	2,051,800 - 3,174,400
1988	45,600	2,356,800	2,402,400	1,808,400 - 2,996,300
1989	196,900	2,119,400	2,316,300	1,836,700 - 2,795,800
1990	69,600	2,114,200	2,183,800	1,886,200 - 2,479,400
1991	60,000	2,333,300	2,393,300	2,116,000 - 2,670,700
1992	145,900	2,027,000	2,172,900	*
1993	188,200	2,277,200	2,465,400	2,151,500 - 2,779,300
1994	142,000	2,468,500	2,610,500	2,266,800 - 2,954,100
1995	213,000	1,796,700	2,009,700	1,724,800 - 2,294,600
1996	161,600	2,137,000	2,298,600	1,749,900 - 2,847,300
1997	239,330	1,924,070	2,163,400	1,907,900 - 2,418,900
1998	150,756	2,178,844	2,329,600	2,033,130 - 2,626,070
1999	57,700	1,246,770	1,306,470	1,118,800 - 1,494,150
2000	73,200	1,508,700	1,581,900	1,382,000 - 1,781,800
2001			1,855,200	1,600,300 - 2,110,000

* 95% confidence intervals cannot be calculated for 1992 since the total estimate includes an unsampled area for which a 3 year average was used as a proxy.

Estimates are given separately for unexploited ages (less than age 7) and exploited ages (ages 7 and older) except for 2000 where age data are not yet available. The data show a doubling of biomass between 1975 and 1979 with a further increase to over 2.3 million t in 1981 for the exploitable portion of the population. Survey abundance estimates fluctuated erratically from 1981 to 1990 with biomass ranging from as high as 3.5 million t in 1983 to as low as 1.9 million t in 1986. Estimates of biomass since 1990 show an even trend at high levels of abundance for yellowfin sole, with the exception of the results from the 1999 and 2000 summer surveys, which are at lower levels.

Indices of relative abundance available from AFSC surveys have also shown a major increase in the abundance of yellowfin sole during the late 1970s increasing from 21 kg/ha in 1975 to 51 kg/ha in 1981 (Fig. 3.2, Bakkala and Wilderbuer 1990). These increases have also been documented through Japanese commercial pair trawl data and catch-at-age modeling in past assessments (Bakkala and Wilderbuer 1990).

Since 1981, the survey CPUEs have fluctuated widely. For example, they increased from 51 kg/ha in 1981 to 84 kg/ha in 1983 and then declined sharply to 49 kg/ha in 1985. They continued to fluctuate from 1986-90, although with less amplitude (Fig 3.2). From 1990-1998, the estimated CPUE was relatively stable but have declined the past two years. Fluctuations of the magnitude shown between 1980 and 1990 and again between 1998 and 1999 are unreasonable considering the combined elements of slow growth and long life span of yellowfin sole and low exploitation rate, characteristics which should produce more gradual changes in abundance.

Variability of yellowfin sole survey abundance estimates are in part due to the availability of yellowfin sole to the survey area (Nichol, 1998). Yellowfin sole are known to undergo annual migrations from wintering areas off the shelf-slope break to nearshore waters where they spawn throughout the spring and summer months (Nichol, 1995; Wakabayashi, 1989; Wilderbuer et al., 1992). Exploratory survey sampling in coastal waters of the eastern Bering Sea indicate that yellowfin sole concentrations can be greater in these shallower areas not covered by the standard AFSC survey. Commercial bottom trawlers have commonly found high concentrations of yellowfin sole in areas such as near Togiak Bay (Low and Narita, 1990) and in more recent years from Kuskokwim Bay to just south of Nunivak Island. The coastline areas are sufficiently large enough to offer a substantial refuge for yellowfin sole from the current survey.

Over the past 15 years survey biomass estimates for yellowfin sole have shown a positive correlation with shelf bottom temperatures (Nichol, 1998); estimates have been low during cold years. The 1999 survey, which was conducted in exceptionally cold waters, indicated a biomass estimate that was unrealistically low. The bottom temperatures during the 2000 survey were much warmer than in 1999, and the biomass increased, but still did not approach estimates from earlier years. Average bottom temperature and biomass both increased again in 2001. Given that both 1999 and 2000 surveys were conducted two weeks earlier than previous surveys, it is possible that the time difference may also have affected the availability of yellowfin sole to the survey. If, for example, the timing of peak yellowfin sole spawning in nearshore waters corresponded to the time of the survey, a greater proportion of the population would be unavailable to the standard survey area.

We propose two possible reasons why survey biomass estimates are lower during years when bottom temperatures are low. First, catchability may be lower because yellowfin sole may be less active when temperatures are low. Less active fish may be less susceptible to herding, and escapement under the footrope of survey gear may increase if fish are less active. Secondly, bottom temperatures may influence the timing of the inshore spawning migrations of yellowfin sole and therefore affect their availability to the survey area.. Because yellowfin sole spawning grounds include nearshore areas outside the survey area, availability of fish within the survey area can vary with the timing of this migration and the timing of the survey. As was the case in 2000, greater than average catches along the survey border outside of Kuskowkim bay may indicate that a significant portion of the biomass lies outside this border (Fig 3.3).

Weight-at-Age and Maturity-at-Age

Mean lengths and weights at age of yellowfin sole based on 12 years (1979-90) of data from AFSC surveys and the length (cm) - weigh t(g) relationship (W = 0.0097217 * L ** 3.0564) are as follows:

Age	Length cm	Length in	Weight g	Weight lb
3	11.1	4.4	15.31	0.03
4	14.5	5.7	34.41	0.08
5	17.4	6.9	60.23	0.13
6	19.9	7.8	90.97	0.20
7	22.1	8.7	124.80	0.27
8	24.0	9.4	160.07	0.35
9	25.6	10.1	195.44	0.43
10	27.0	10.6	229.92	0.51
11	28.2	11.1	262.79	0.58
12	29.2	11.5	293.59	0.65
13	30.1	11.9	322.06	0.71
14	30.9	12.2	348.09	0.77
15	31.6	12.4	371.67	0.82
16	32.1	12.6	392.87	0.87
17	32.6	12.8	411.81	0.91
18	33.1	13.0	428.65	0.94
19	33.5	13.2	443.55	0.98
20	33.8	13.3	456.69	1.01
21	34.0	13.4	468.25	1.03
22	34.3	13.5	478.38	1.05
23	34.5	13.6	487.24	1.07
24	34.7	13.7	494.99	1.09
25	34.8	13.7	501.74	1.11
26	34.9	13.7	507.61	1.12

Maturity information collected from yellowfin sole females during the 1992 and 1993 eastern Bering Sea trawl surveys is used in this assessment (Table 3.4). Nichol (1994) estimated the age of 50% maturity at 10.5 years based on the histological examination of 639 ovaries. In the case of most north Pacific flatfish species, including yellowfin sole, sexual maturity occurs well after the age of entry into the fishery. Yellowfin sole are 90% selected to the fishery by age 11 but females have been found to be only 50% mature at this age.

Length-at-Age

Parameters of the von Bertalanffy growth curve for yellowfin sole from 12 years of combined data have been estimated as follows:

age range	L_{inf} (cm)	K	t_0
3-26	35.8	0.147	0.47

ANALYTIC APPROACH

Model Structure

The abundance, mortality, recruitment and selectivity of yellowfin sole were assessed with a stock assessment model using the AD Model builder language. The conceptual model is similar to that implemented in the stock synthesis program (Methot 1990, Fournier and Archibald 1982). The model is a separable catch-age analysis that uses survey estimates of biomass and age composition as auxiliary information. The assessment model simulates the dynamics of the population and compares the expected values of the population characteristics to the characteristics observed from surveys and fishery sampling programs. This is accomplished by the simultaneous estimation of the parameters in the model using the maximum likelihood estimation procedure. The fit of the simulated values to the observable characteristics is optimized by maximizing a log(likelihood) function.

The suite of parameters estimated by the model are classified by three likelihood components:

Data Component	Distribution assumption
Trawl fishery catch-at-age	Multinomial
Trawl survey population age composition	Multinomial
Trawl survey biomass estimates and S.E.	Log normal

The total log likelihood is the sum of the likelihoods for each data component (Table 3.5). The likelihood components may be weighted by an emphasis factor, however, equal emphasis was placed on fitting each likelihood component in the yellowfin sole assessment except for the catch. The AD Model Builder software fits the data components using automatic differentiation (Griewank and Corliss 1991) software developed as a set of libraries (AUTODIFF C++ library). Table 3.5 presents the key equations used to model the yellowfin sole population dynamics in the Bering Sea and Table 3.6 provides a description of the variables used in Table 3.5.

Sharp increases in trawl survey abundance estimates for most species of Bering Sea flatfish between 1981 and 1982 indicate that the 83-112 trawl was more efficient for capturing these species than the 400-mesh eastern trawl used in 1975, and 1979-81. Allowing the model to tune to these early survey estimates would most likely underestimate the true pre-1982 biomass, thus exaggerating the degree to which biomass increased during that period. Although this underestimate would have little effect on the estimate of current yellowfin sole biomass, it would affect the spawner and recruitment estimates for the time-series. Hence, the pre-1982 survey biomass estimates were omitted from the analysis.

The model of yellowfin sole population dynamics was evaluated with respect to the observations of the time-series of survey and fishery age compositions and the survey biomass trend since 1982.

Parameters Estimated Independently

Natural mortality (M) was initially estimated by a least squares analysis. Catch-at-age data were fitted to Japanese pair trawl effort data while varying the catchability coefficient (q) and M simultaneously. The best fit to the data (the point where the residual variance was minimized) produced an M value of 0.12 (Bakkala and Wespestad 1984).

The natural mortality rate value of 0.12 was also evaluated using the synthesis model in an earlier assessment (Wilderbuer 1992). Values of natural mortality were varied from 0.09 to 0.18 to determine which level would fit the observable population characteristics best. Maximum log(likelihood) values occurred at M = 0.12 when the analysis was run using fishery catch-at-age data from 1977-91 and at M = 0.16 when data from 1964-91 were included. The natural mortality rate most likely falls within the range of 0.12 - 0.16.

Yellowfin sole maturity schedules were estimated as discussed in section 3.3.3 (Table 3.4).

Parameters Estimated Conditionally

The parameters estimated by the base model are presented below:

Fishing mortality	Selectivity	Year class strength	Total
48	4	67	119

The increase in the number of parameters estimated in this assessment compared to last year can be accounted for by the input of another year of fishery data and the entry of another year class into the observed population.

Year class strengths

The population simulation specifies the numbers-at-age in the beginning year of the simulation, the number of recruits in each subsequent year, and the survival rate for each cohort as it moves through the population using the population dynamics equations given in Table 3.5.

Selectivity

Fishery and survey selectivity was modeled in this assessment using the two parameter formulation of the double logistic function, as shown in Table 3.5. The model was run with the selectivity curve fixed asymptotically for the older fish in the fishery and survey, but still was allowed to estimate the shape of the logistic curve for young fish. The oldest year classes in the surveys and fisheries were truncated at 20 and allowed to accumulate into the age category 20+ years.

Fishing Mortality

The fishing mortality rates (F) for each age and year are calculated to approximate the catch weight by solving for F while still allowing for observation error in catch measurement. A large emphasis was placed on the catch likelihood component.

Survey Catchability

Last year's assessment (Wilderbuer and Nichol 2000) and this assessment have reported a relationship between estimates of survey biomass and bottom water temperature. To better understand how water temperature may affect the catchability of yellowfin sole to the survey trawl, we estimated catchability for each year in the stock assessment model as:

$$q = \alpha + \beta T$$

where q is catchability, T is the average annual bottom water temperature at survey stations less than 100 m, and -α and β are parameters estimated by the model. The result of the linear fit to bottom temperature vs. estimated q is shown in Figure 3.4.

Model Evaluation

Description of Alternative Models

Past assessment models have not estimated survey catchability (q) and have set it equal to 1.0. Since the analysis in the previous section indicates that the bottom trawl survey catchability may vary annually with bottom water temperature, an alternative model (Model C) estimates q annually as a linear function of bottom water temperature. A third model (Model B) estimates a single q for the entire time series.

Criteria to select final model

Model selection criteria will include:

1) The root mean squared error (RMSE) of the fit to the survey biomass data.
2) The -log(likelihood) for all data combined.
3) The likelihood profile of q.

The RMSE s for the three models indicate that Model C provides the best fit to the survey biomass (see Table below and Figure 3.5).

	Model A (q = 1.0)	**Model B (q estimated)**	**Model C (q fit with bottom temperature)**
RMSE	0.194	0.163	0.128
	-log(likelihood)		
trawl survey abundance	42.83	28.58	18.20
fishery catch	0.0042	0.0043	0.0042
survey age	457.18	452.92	452.75
fishery age	1176.55	1178.67	1178.88
recruitment	25.25	24.65	24.63
total -log(likelihood)	1701.82	1684.82	1674.47

Recall that Model B has one more estimated parameter than Model A and that Model C has one more estimated parameter than Model B. Given these differences in the number of estimated parameters, a difference of more than 1.92 in the -log(likelihood) between Models B and A and Models C and B is a significant improvement at the 5% level (Polacheck et al. 1993). Under this criterion, Model B has a significantly better fit than Model A, and Model C has a significantly better fit than Model B.

The likelihood profile of q indicates a small variance with a narrow range of likely values (Figure 3.6). The probability of q being as low or lower than the value of 1.0 assumed in Model A, given the data, appears to be very low. The model of choice for this assessment is Model C because it provides a significantly better fit to the data overall, and because the value of 1.0 assumed in Model A no longer appears tenable.

MODEL RESULTS

Fishing Mortality and Selectivity

The assessment model estimates of the annual fishing mortality on fully selected ages is given in Table 3.7. The large 1997 catch corresponds to a full-selection F value of 0.16, which is higher than the 1977-2000 average full selection-F of 0.11 but only represents an exploitation fraction of 10%. Selectivities estimated by the model (Table 3.8, Figure 3.7) indicate that yellowfin sole are 50% selected by the fishery at age 9 and nearly fully selected by age 13.

Abundance Trend

Model C estimates q at an average value of 1.36 for the period 1982-2001 which results in the reduction of the estimate of the 2001 biomass to 68% of the level of the model (Model A) used in last years assessment (Table 3.9). Model results indicate that yellowfin sole total biomass (age 2+) was at low levels during most of the 1960s and early 1970s (600,000-800,000 t) after a period of high exploitation (Table 3.9, Figure 3.7, bottom left panel). Sustained above average recruitment from 1967-76 combined with light exploitation resulted in a biomass increase to nearly 2.5 million t by 1985. The population biomass has since been in a slow decline as the strong 1981 and 1983 year-classes have passed through the population with only the 1991 year class at levels observed during the 1970s. Over the past fifteen years stock biomass has declined 1 million t since the peak biomass observed in 1985 and is estimated at 1.6 million t in 2002..

The female spawning biomass has also steadily declined since the peak in 1985, with a 2001 estimate of 473,000 t (30% decline). The resulting fit to all the observed fishery and survey age compositions input into the model are shown in the Appendix. The fit to the trawl survey biomass estimates are shown in Figure 3.5. Allowing q to be correlated with annual bottom temperature provides a close fit to the bottom trawl survey estimates (Table 3.9).

Both the trawl survey and the stock assessment model indicate that the yellowfin sole resource slowly increased during the 1970s and early 1980s to a peak level during the mid-1980s and that the resource has been in a slow, consistent decline since then (Figure 3.7). Above average recruitment from the 1991 year-class is expected to maintain the abundance of yellowfin sole at a level above B_{40} in the near future. The stock assessment projection model (later section) indicates a continued slow decline in female spawning biomass in the near future if the fishing mortality rate continues at the same level as the average of the past 5 years.

Total Biomass

The stock assessment model estimate of total biomass (begin year population numbers multiplied by mid-year weight at age) is used to recommend the ABC for 2002. Including the 2001 reported catch through 15 September (including discards), the model projects the total biomass for 2002 at **1,596,800 t**.

Recruitment Trends

The primary reason for the sustained increase in abundance of yellowfin sole during the 1970s and early 1980s was the recruitment of a series of stronger than average year classes spawned in 1967-76 (Figure 3.8 and Table 3.11). The 1981 year class is the strongest observed (and estimated) during the 46 year period analyzed and the 1983 year class is also very strong. Survey age composition estimates and the assessment model also estimate that the 1987 and 1988 year classes were average and the 1991 year class is strong. With the exception of these three year classes, recruitment over the past 13 years has been below the 48 year average which has caused the population decline.

Spawner-Recruit Relationship

The relationship between the model estimates of female spawning biomass and age 5 recruitment are shown in Figure 3.9. The forty-five data points were fit with a Ricker (1958) form of spawner-recruit curve. Estimation of recruitment using these data indicate that good year classes may result at high or low spawning stock size. However, estimation of MSY using these data is not recommended for management purposes since environmental processes which can determine the level of recruitment for a given stock size are not considered.

Historical Exploitation Rates

Based on results from the stock assessment model, annual exploitation rates of yellowfin sole ranged from 3 to 10% of the total biomass since 1977, and have averaged 6% (Table 3.7).

ACCEPTABLE BIOLOGICAL CATCH

After increasing during the 1970s and early 1980s, estimates from the stock assessment model indicate the total biomass has been at a slow decline from high levels of stock biomass since the peak in 1985. The 2002 estimate of total biomass is 1,596,800 t.

The reference fishing mortality rate for yellowfin sole is determined by the amount of population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Equilibrium female spawning biomass is calculated by applying the female spawning biomass per recruit resulting from a constant $F_{0.40}$ harvest to an estimate of average equilibrium recruitment. For the 2002 assessment, the Alaska Fisheries Science Center policy is to use only year classes spawned in 1977 or later to calculate the average equilibrium recruitment if no compelling reason exists to do otherwise. Using the time-series of recruitment numbers from 1978-2000 from the stock assessment model results in an estimate of **$B_{0.40}$ = 392,200 t**. The stock assessment projection model estimates the 2002 level of female spawning biomass at 453,700 t (B). Since reliable estimates of B, $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B>B_{0.40}$ (453,700 > 392,200, Figure 3.10), yellowfin sole reference fishing mortality is defined in tier 3a. For the 2002 harvest: $F_{ABC} \leq F_{0.40} = 0.11$ (full selection F values).

Acceptable biological catch is estimated for 2002 by applying the $F_{0.40}$ fishing mortality rate and age-specific fishery selectivities to the 2002 estimate of age-specific total biomass as follows:

$$ABC = \sum_{a=a_r}^{a_{\max}} \overline{w}_a n_a \left(\frac{Fs_a}{M + Fs_a} \right) \left(1 - e^{-M - Fs_a}\right)$$

where S_a is the selectivity at age, M in natural mortality, W_a is the mean weight at age, and n_a is the beginning of the year numbers at age. **This calculation results in a 2002 ABC of 114,900 t**.

Overfishing

The stock assessment analysis must also consider harvest limits, usually described as "overfishing" fishing mortality levels with corresponding yield amounts. Previous stock assessments used $F_{0.30}$ or the fishing mortality rate which would reduce the spawning biomass per recruit to 35% of its unfished level as the harvest limit. Amendment 56 to the BS/AI FMP now sets the harvest limit at the $F_{0.35}$ fishing mortality value. The overfishing fishing mortality value, ABC fishing mortality value and their corresponding yields are given as follows:

Harvest level	F value	2002 Yield
$F_{OFL} = F_{0.35}$	0.13	136,400 t
$F_{ABC} = F_{0.40}$	0.11	114,900 t

BIOMASS PROJECTIONS

This year, a standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2001 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2000 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2001. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2002, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2002 recommended in the assessment to the *max* F_{ABC} for 2002. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 1996-2000 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above ½ of its MSY level in 2002 and above its MSY level in 2012 under this scenario, then the stock is not overfished.)

Scenario 7: In 2002 and 2003, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2014 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results shown in Table 3.12 and Figure 3.11 indicate that yellowfin are not currently overfished and are not approaching an overfished condition.

OTHER CONSIDERATIONS

Groundfish predators of yellowfin sole include Pacific cod, skates and Pacific halibut, mostly on fish ranging from 7 to 25 cm standard length. Yellowfin sole diet consists mainly of bivalves, polychaetes, amphipods and echiurids.

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Appendix

1) 2000 fishery locations by quarter. Catches where yellowfin sole comprised 20% or more of the catch are indicated as darker circles.

2) Figures showing the fit of the stock assessment model to the time-series of fishery and trawl survey age compositions (survey and fishery observations are the solid lines).

3) Table of yellowfin sole catch from surveys conducted in the eastern Bering Sea and Aleutian Islands area, 1977-98.

Table 3.4--Female yellowfin sole proportion mature at age from Nichol (1994).

Age	Proportion mature
1	0
2	0
3	.001
4	.004
5	.008
6	.020
7	.046
8	.104
9	.217
10	.397
11	.612
12	.790
13	.899
14	.955
15	.981
16	.992
17	.997
18	1.0
19	1.0
20	1.0

Table 3.1- Catch of yellowfin sole 1977-2001. Catch for 2001 is the total through September 15, 2001.

		Domestic		
Year	Foreign	JVP	DAP	Total
1977	58,373			58,373
1978	138,433			138,433
1979	99,019			99,019
1980	77,768	9,623		87,391
1981	81,255	16,046		97,301
1982	78,331	17,381		95,712
1983	85,874	22,511		108,385
1984	126,762	32,764		159,526
1985	100,706	126,401		227,107
1986	57,197	151,400		208,597
1987	1,811	179,613	4	181,428
1988		213,323	9,833	223,156
1989		151,501	1,664	153,165
1990		69,677	14,293	83,970
1991			115,842	115,842
1992			149,569	149,569
1993			106,101	106,101
1994			144,544	144,544
1995			124,740	124,740
1996			129,659	129,659
1997			181,389	181,389
1998			101,201	101,201
1999			67,320	67,320
2000			83,850	83,850
2001			35,9380	35,938

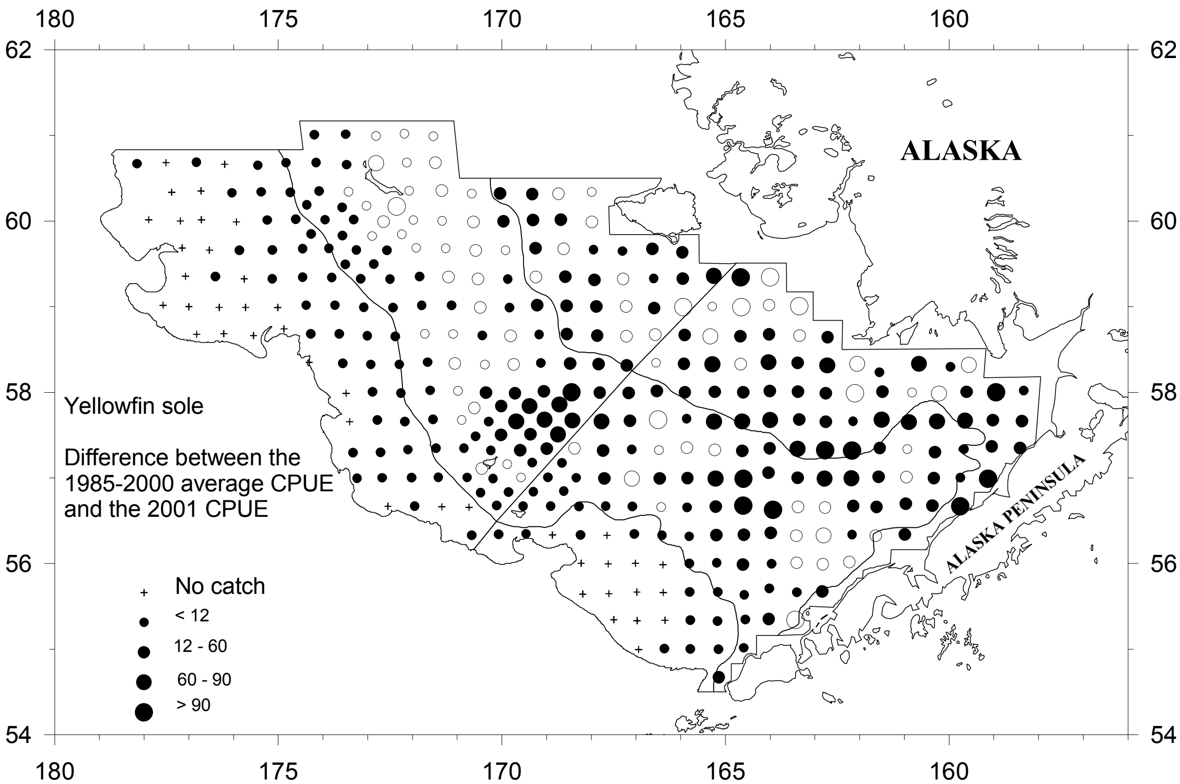

Figure 3.3–Difference between the 1995-2000 average trawl survey CPUE for yellowfin sole and the 2001 survey CPUE.

Table 3-5.–Key equations used in the population dynamics model.

$N_{t,1} = R_t = R_0 e^{\tau_t}, \quad \tau_t \sim N(0, \delta^2{}_R)$	Recruitment 1945-64
$N_{t,1} = R_t = R_\gamma e^{\tau_t}, \ \tau_t \sim N(0, \delta^2{}_R)$	Recruitment 1965-96
$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}}\left(1 - e^{-z_{t,a}}\right) N_{t,a}$	Catch in year *t* for age *a* fish
$N_{t+1,a+1} = N_{t,a} e^{-z_{t,a}}$	Numbers of fish in year *t+1* at age *a*
$N_{t+1,A} = N_{t,A-1} e^{-z_{t,A-1}} + N_{t,A} e^{-z_{t,A}}$	Numbers of fish in the "plus group"
$S_t = \sum N_{t,a} W_{t,a} \phi_a$	Spawning biomass
$Z_{t,a} = F_{t,a} + M$	Total mortality in year *t* at age *a*
$F_{t,a} = s_a \mu^F \exp^{\varepsilon^F{}_t}, \ \varepsilon^F{}_t \sim N(o, \sigma^2{}_F)$	Fishing mortality
$s_a = \frac{1}{1 + \left(e^{-\alpha + \beta a}\right)}$	Age-specific fishing selectivity
$C_t = \sum C_{t,a}$	Total catch in numbers
$P_{t,a} = {}^{C_{t,a}}\!/\!{}_{C_t}$	Proportion at age in catch
$SurB_t = q \sum N_{t,a} W_{t,a} v_a$	Survey biomass
$L = \sum_{t,a} m_t p_{t,a} \ln \frac{\hat{p}_{t,a}}{p_{t,a}} + (-0.5) \sum_t \left[\left(\ln \frac{surB_t}{\hat{surB}_t} \ {}^{1}\!/\!{}_{\sigma_t} \right)^2 - \ln \sigma_t \right]$	Total log likelihood

Table 3-6.–Variables used in the population dynamics model.

Variables

R_t	Age 1 recruitment in year *t*
R_0	Geometric mean value of age 1 recruitment, 1945-64
R_γ	Geometric mean value of age 1 recruitment, 1965-96
τ_t	Recruitment deviation in year *t*
$N_{t,a}$	Number of fish in year *t* at age *a*
$C_{t,a}$	Catch numbers of fish in year *t* at age *a*
$P_{t,a}$	Proportion of the numbers of fish age *a* in year *t*
C_t	Total catch numbers in year *t*
$W_{t,a}$	Mean body weight (kg) of fish age *a* in year *t*
ϕ_a	Proportion of mature females at age *a*
$F_{t,a}$	Instantaneous annual fishing mortality of age *a* fish in year *t*
M	Instantaneous natural mortality, assumed constant over all ages and years
$Z_{t,a}$	Instantaneous total mortality for age *a* fish in year *t*
s_a	Age-specific fishing gear selectivity
μ^F	Median year-effect of fishing mortality
ε_t^F	The residual year-effect of fishing mortality
ν_a	Age-specific survey selectivity
α	Slope parameter in the logistic selectivity equation
β	Age at 50% selectivity parameter in the logistic selectivity equation
σ_t	Standard error of the survey biomass in year *t*

TABLE 3.2-YELLOWFIN SOLE FISHERY CATCH-AT-AGE IN NUMBERS (millions), 1977-2000.

YEAR/AGI	7	8	9	10	11	12	13	14	15	16	17+
1977	18.7	42.5	35.7	70.5	48.3	15.8	4.7	2.9	2.2	0.6	0.3
1978	66.8	131.7	113.8	97.8	104.3	38.9	21.6	12.3	4.5	2.7	0.7
1979	20.7	49.4	89.6	82.9	61.3	45.1	22.9	7.1	4.1	1.5	1.3
1980	33.1	19.7	41.3	64.1	60.8	47.7	42.4	23.2	7.4	10.1	4.2
1981	31.1	46.2	41.7	51.7	67.2	70.6	58.4	40.2	18.5	5.7	4.4
1982	27.7	58.9	45.1	42.2	71.5	75.0	39.6	20.1	10.4	2.7	0.5
1983	56.2	39.6	75.9	53.5	53.5	77.1	57.9	32.3	16.5	5.2	2.9
1984	13.2	26.3	34.0	70.5	72.2	94.1	107.8	102.1	56.5	23.6	11.3
1985	36.9	52.1	107.2	106.0	127.9	108.8	108.5	103.9	66.1	29.5	15.4
1986	49.3	40.7	67.6	111.6	82.5	74.7	64.3	40.2	56.5	51.8	28.8
1987	18.2	49.4	33.5	49.3	55.4	59.6	73.4	61.0	26.3	40.1	42.3
1988	29.0	57.5	140.5	40.8	71.7	89.4	53.6	104.1	82.1	34.8	176.9
1989	2.5	33.8	47.0	73.1	29.5	20.5	52.0	32.2	45.3	44.5	172.0
1990	8.8	7.0	52.4	29.2	49.4	20.0	18.4	16.9	17.4	23.2	72.2
1991	9.9	62.5	6.5	116.2	28.8	38.8	7.3	18.5	25.5	16.0	60.3
1992	5.9	24.2	83.8	22.5	123.3	29.9	25.0	13.3	15.2	12.7	71.8
1993	12.2	8.1	11.0	57.4	7.4	74.4	16.3	19.9	9.8	15.1	89.9
1994	21.3	33.7	26.8	26.9	127.5	3.2	90.8	9.7	33.9	13.7	85.6
1995	27.7	46.3	21.0	11.2	13.7	83.3	1.8	103.9	9.7	16.9	69.4
1996	13.1	41.1	43.8	19.4	15.5	25.9	74.2	14.3	75.4	10.6	73.6
1997	19.5	25.2	63.6	40.2	27.4	38.5	29.8	114.7	14.3	63.5	114.4
1998	12.2	13.2	15.7	33.2	28.6	20.0	15.8	16.8	28.2	15.3	100.3
1999	2.77	6.97	7.20	7.59	24.45	18.68	10.29	11.66	14.69	20.14	66.89
2000	1.28	7.72	24.69	10.50	11.66	29.30	25.37	19.02	8.89	20.06	21.35

Table 3.3--Trawl survey estimates of yellowfin sole population numbers at age 1982-2000 (milions)

YEAR/AGI	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17+
1982	123.92	363.40	742.81	2882.02	3155.60	2408.06	3193.93	1445.10	1556.82	1258.34	1140.63	863.75	531.61	163.76	73.56	90.30
1983	0.00	6.51	142.01	378.56	1659.47	3495.21	1836.08	2388.32	1786.45	1596.73	2079.66	1576.73	771.86	751.40	154.05	114.31
1984	0.00	115.73	494.28	577.04	957.63	1554.66	1765.76	1832.76	1982.22	1759.32	953.15	1018.81	723.36	580.14	310.55	251.42
1985	0.00	43.18	241.90	762.09	1040.18	618.98	1206.24	1353.31	787.50	904.66	846.54	568.07	519.45	448.47	295.50	177.82
1986	0.00	35.15	66.88	310.90	698.31	1297.69	535.40	888.12	787.86	693.12	482.52	507.65	302.11	449.96	212.17	496.40
1987	0.00	6.42	102.16	210.91	1554.66	932.70	1477.58	681.56	649.96	818.80	534.89	552.59	319.38	381.16	392.15	1198.97
1988	1.05	4.01	32.02	782.57	133.73	2997.03	1524.25	1271.78	318.99	500.79	446.73	464.61	821.54	547.60	290.81	1.76
1989	0.00	17.04	45.57	336.77	1847.96	504.12	3244.51	1350.68	978.98	255.00	280.08	503.42	351.80	540.72	267.24	1295.95
1990	0.00	29.10	116.55	220.85	637.65	1947.17	386.52	2400.18	726.23	746.35	141.64	137.63	174.89	102.42	286.12	1003.59
1991	0.00	12.92	229.34	594.04	256.28	718.66	1933.06	207.09	2423.15	535.68	764.55	142.83	196.50	137.61	164.88	1220.88
1992	0.00	12.71	281.70	670.10	854.01	386.54	436.94	1522.33	183.38	1526.22	232.18	467.06	128.03	133.92	203.93	1149.53
1993	0.00	52.78	180.61	610.32	1300.31	828.16	548.03	471.74	2418.53	147.79	1725.10	225.96	222.99	119.53	67.92	1059.59
1994	4.24	75.20	165.77	388.84	944.64	1857.40	1210.83	789.04	475.32	1992.18	25.72	1137.87	89.67	405.69	153.48	434.45
1995	0.00	18.90	321.67	408.22	451.40	1555.61	1192.14	368.72	314.47	99.90	1111.24	33.90	1163.38	153.19	104.54	929.92
1996	0.00	92.33	248.64	1649.80	536.75	513.25	877.81	878.98	555.07	295.42	299.57	1026.43	181.20	1115.82	179.63	1151.40
1997	0.00	37.69	541.59	927.90	1522.86	436.97	422.70	952.22	473.65	307.94	390.50	292.35	1014.11	122.74	578.36	948.94
1998	0.00	58.92	153.23	829.25	989.47	1732.39	418.81	429.94	574.20	685.32	715.00	320.56	333.60	452.87	179.95	1974.36
1999	0.00	8.82	169.07	343.88	402.87	430.49	1307.45	250.52	201.63	555.35	460.84	261.72	126.15	131.30	296.15	1974.36
2000	0.00	24.50	134.75	527.47	417.21	594.20	791.41	1020.82	268.87	383.99	320.12	344.41	278.76	264.25	233.10	1314.46

Table 3.7--Model estimates of yellowfin sole fishing mortality and exploitation rate (catch/total biomass).

Year	Full selection F	Exploitation Rate
1954	0.0105	0.0079
1955	0.0124	0.0090
1956	0.0214	0.0146
1957	0.0217	0.0137
1958	0.0408	0.0240
1959	0.1843	0.0979
1960	0.5660	0.2522
1961	1.0678	0.3808
1962	1.5937	0.4183
1963	0.4875	0.1232
1964	0.5835	0.1517
1965	0.2351	0.0731
1966	0.3609	0.1298
1967	0.5605	0.2079
1968	0.2957	0.1195
1969	0.6499	0.2330
1970	0.6358	0.2041
1971	1.0230	0.2485
1972	0.3540	0.0747
1973	0.5152	0.0995
1974	0.2186	0.0455
1975	0.2447	0.0571
1976	0.1562	0.0421
1977	0.1206	0.0374
1978	0.2287	0.0774
1979	0.1349	0.0516
1980	0.0976	0.0421
1981	0.0914	0.0439
1982	0.0778	0.0413
1983	0.0785	0.0450
1984	0.1081	0.0645
1985	0.1538	0.0917
1986	0.1470	0.0867
1987	0.1341	0.0775
1988	0.1754	0.0974
1989	0.1242	0.0703
1990	0.0629	0.0378
1991	0.0701	0.0443
1992	0.1149	0.0748
1993	0.0774	0.0522
1994	0.1081	0.0727
1995	0.0985	0.0655
1996	0.1072	0.0705
1997	0.1603	0.1027
1998	0.0968	0.0616
1999	0.0663	0.0421
2000	0.0833	0.0527

Table 3.8--Model estimates of yellowfin sole age-specific selectivities for survey and fishery data.

Age	Fishery (1964-2000)	Survey (1982-2000)
1	0.000	0.002
2	0.001	0.007
3	0.002	0.032
4	0.006	0.130
5	0.016	0.400
6	0.043	0.749
7	0.111	0.930
8	0.259	0.983
9	0.493	0.996
10	0.731	0.999
11	0.883	1.000
12	0.955	1.000
13	0.983	1.000
14	0.983	1.000
15	0.983	1.000
16	0.983	1.000
17	0.983	1.000
18	0.983	1.000
19	0.983	1.000
20	0.983	1.000

Table 3.9-Model estimates of yellowfin sole 2+ biomass and begin-year female spawning biomass from the 2000 and 2001 stock assessments.

	2000 Assessment		2001 Assessment	
Year	Female Spawning Biomass	Age 2+ Total Biomass	Female Spawning Biomass	Age 2+ Total Biomass
1964	72,879	736,640	72,142	733,033
1965	75,688	740,311	74,707	736,123
1966	100,678	793,814	99,598	788,623
1967	117,770	786,899	116,608	780,210
1968	112,325	713,371	111,002	704,279
1969	123,005	730,512	121,507	717,376
1970	99,244	671,202	97,381	652,036
1971	81,988	673,680	79,664	645,541
1972	54,231	681,114	51,359	640,424
1973	62,515	843,947	58,730	785,977
1974	69,564	1,007,430	64,219	927,458
1975	96,496	1,239,690	88,649	1,133,220
1976	131,434	1,473,360	119,646	1,335,930
1977	183,098	1,732,990	165,601	1,561,190
1978	249,325	1,996,810	224,113	1,788,340
1979	304,421	2,166,450	269,215	1,920,570
1980	382,599	2,357,070	335,341	2,075,140
1981	475,092	2,532,370	413,837	2,216,570
1982	568,113	2,666,060	491,703	2,319,120
1983	661,780	2,786,600	569,620	2,408,550
1984	746,213	2,880,850	638,377	2,471,950
1985	797,979	2,916,380	675,679	2,476,320
1986	801,944	2,874,980	667,439	2,405,050
1987	791,003	2,840,250	646,543	2,342,180
1988	778,541	2,813,850	625,340	2,291,060
1989	741,577	2,722,790	580,946	2,179,820
1990	744,213	2,693,740	573,999	2,130,760
1991	787,128	2,727,210	605,350	2,144,850
1992	827,640	2,724,700	633,829	2,125,740
1993	833,714	2,647,800	629,727	2,032,500
1994	848,123	2,624,120	635,717	1,989,120
1995	827,767	2,560,320	610,719	1,903,910
1996	804,766	2,519,270	584,574	1,837,870
1997	776,934	2,471,850	553,640	1,765,470
1998	729,887	2,369,650	502,320	1,642,200
1999	718,707	2,348,180	484,524	1,600,920
2000	722,269	2,355,290	480,302	1,592,370
2001			473,070	1,571,180

Table 3.10--Model estimates of yellowfin sole population numbers (millions) from 1954-2001.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1954	2.90266	4.09952	2.23931	0.914883	0.442673	0.379041	0.357662	0.350447	0.340284	0.326893	0.325346	0.324034	0.322491	0.32061	0.31939	0.31887	0.318535	0.318267	0.318117	0.318018
1955	1.3632	2.57442	3.63592	1.98605	0.81138	0.392551	0.336028	0.316848	0.309978	0.300251	0.28772	0.285901	0.284536	0.283096	0.281444	0.280374	0.279918	0.279623	0.279388	0.558425
1956	0.869103	1.20905	2.28329	3.22469	1.76134	0.719488	0.347975	0.297619	0.280118	0.273248	0.263895	0.252403	0.250585	0.2493	0.248039	0.246591	0.245653	0.245254	0.244995	0.734061
1957	3.11778	0.770821	1.07231	2.025	2.85969	1.56164	0.637541	0.307891	0.262504	0.24583	0.238583	0.229664	0.219326	0.217613	0.216497	0.215402	0.214145	0.21333	0.212983	0.850233
1958	2.30644	2.76521	0.683646	0.951014	1.79579	2.53545	1.38376	0.564087	0.271549	0.230347	0.214609	0.207595	0.199526	0.190427	0.188939	0.18797	0.18702	0.185928	0.185221	0.923122
1959	1.74401	2.04561	2.45244	0.606288	0.843275	1.5917	2.24479	1.22172	0.49504	0.236039	0.198292	0.183596	0.177079	0.169997	0.162245	0.160977	0.160152	0.159342	0.158412	0.944314
1960	1.83686	1.54672	1.81404	2.17429	0.53716	0.745736	1.40057	1.95054	1.03311	0.400916	0.182975	0.149453	0.136566	0.131026	0.125787	0.12005	0.119113	0.118502	0.117902	0.815944
1961	1.05835	1.6289	1.37124	1.60703	1.92216	0.472162	0.645511	1.16637	1.49429	0.693107	0.235145	0.098441	0.077218	0.069428	0.066612	0.063948	0.061032	0.060555	0.060245	0.474754
1962	1.83029	0.938405	1.44356	1.2135	1.41659	1.67618	0.399982	0.50837	0.78473	0.782703	0.28173	0.081213	0.0315	0.023967	0.021549	0.020675	0.019848	0.018943	0.018795	0.166053
1963	0.901868	1.62263	0.831306	1.27611	1.06647	1.22505	1.3882	0.297098	0.298515	0.317129	0.216645	0.061151	0.015729	0.00583	0.004435	0.003988	0.003826	0.003673	0.003506	0.034209
1964	0.854545	0.799782	1.43862	0.736559	1.12864	0.938587	1.06399	1.16621	0.232275	0.208177	0.196982	0.124923	0.034053	0.008638	0.003201	0.002436	0.00219	0.002101	0.002017	0.020712
1965	1.1994	0.757796	0.709035	1.27441	0.651082	0.991794	0.81183	0.884339	0.889377	0.154488	0.120544	0.104347	0.063471	0.017016	0.004316	0.0016	0.001217	0.001094	0.00105	0.011357
1966	1.43247	1.06371	0.671987	0.628552	1.12877	0.57531	0.870799	0.701439	0.738055	0.702463	0.115396	0.08687	0.073945	0.044677	0.011978	0.003038	0.001126	0.000857	0.00077	0.008734
1967	2.36292	1.27036	0.943172	0.595554	0.556321	0.995417	0.502399	0.741925	0.566652	0.547859	0.47861	0.074412	0.05459	0.045991	0.027788	0.00745	0.00189	0.0007	0.000533	0.005911
1968	2.56231	2.09541	1.12624	0.835549	0.526511	0.489046	0.861837	0.418642	0.569186	0.381188	0.322614	0.258739	0.038647	0.027902	0.023507	0.014203	0.003808	0.000966	0.000358	0.003294
1969	2.49033	2.27239	1.85805	0.998277	0.739808	0.464789	0.428267	0.739639	0.343954	0.436321	0.272394	0.22037	0.173042	0.025629	0.018504	0.015589	0.009419	0.002525	0.000641	0.002422
1970	3.4308	2.20834	2.01445	1.64573	0.882092	0.649424	0.400874	0.353338	0.554463	0.221403	0.240695	0.136083	0.105095	0.081006	0.011998	0.008662	0.007298	0.004409	0.001182	0.001434
1971	4.17406	3.04233	1.9577	1.78431	1.45431	0.774498	0.560459	0.331258	0.265846	0.359402	0.123403	0.121755	0.065779	0.049886	0.038452	0.005695	0.004112	0.003464	0.002093	0.001242
1972	4.03546	3.70105	2.69625	1.73265	1.57327	1.2691	0.657365	0.443593	0.225468	0.14236	0.150949	0.04434	0.040663	0.021336	0.016181	0.012472	0.001847	0.001334	0.001124	0.001082
1973	3.5895	3.57879	3.28167	2.38961	1.5336	1.38755	1.10859	0.560507	0.358993	0.167935	0.097483	0.097931	0.028048	0.025463	0.01336	0.010132	0.00781	0.001157	0.000835	0.001381
1974	3.91832	3.18317	3.17289	2.90748	2.11313	1.34912	1.20369	0.92845	0.435084	0.246959	0.102223	0.054854	0.053113	0.01499	0.013608	0.00714	0.005415	0.004174	0.000618	0.001184
1975	4.68567	3.47504	2.82276	2.81283	2.57547	1.8677	1.18537	1.04193	0.778182	0.346451	0.186703	0.074748	0.039489	0.037997	0.010724	0.009735	0.005108	0.003874	0.002986	0.00129
1976	2.97332	4.15554	3.08152	2.50229	2.49125	2.27539	1.63917	1.02309	0.867414	0.611728	0.256972	0.133409	0.052485	0.027534	0.026495	0.007477	0.006788	0.003562	0.002701	0.002981
1977	3.4581	2.63699	3.68521	2.73218	2.21734	2.20407	2.00458	1.42875	0.871446	0.712274	0.484023	0.198537	0.101928	0.039921	0.020943	0.020152	0.005687	0.005163	0.002709	0.004322
1978	2.2818	3.06696	2.33859	3.26767	2.42155	1.96285	1.94473	1.75421	1.22827	0.728288	0.578465	0.385931	0.156943	0.080297	0.031449	0.016499	0.015876	0.00448	0.004068	0.005539
1979	1.50701	2.02365	2.71969	2.07316	2.89436	2.13995	1.72386	1.68148	1.46644	0.973171	0.546525	0.41921	0.275145	0.111163	0.056874	0.022275	0.011686	0.011245	0.003173	0.006804
1980	2.8233	1.33655	1.79464	2.41147	1.8373	2.56158	1.88699	1.50615	1.44019	1.21692	0.782133	0.430297	0.32689	0.213728	0.086349	0.044179	0.017303	0.009077	0.008735	0.007751
1981	2.02154	2.50398	1.18533	1.59138	2.13759	1.62702	2.2624	1.65552	1.30251	1.21728	1.005	0.636374	0.347671	0.263385	0.172207	0.069574	0.035596	0.013942	0.007314	0.013283
1982	5.52873	1.7929	2.22068	1.05109	1.41069	1.89312	1.43738	1.98625	1.43398	1.10428	1.00985	0.82219	0.517227	0.28184	0.213514	0.1396	0.0564	0.028856	0.011302	0.016697
1983	0.882204	4.90344	1.59007	1.96925	0.931818	1.24963	1.67345	1.26386	1.72656	1.22398	0.925313	0.836211	0.677043	0.424973	0.23157	0.175431	0.1147	0.046341	0.023709	0.023005
1984	4.49298	0.782428	4.34871	1.41004	1.74578	0.82542	1.10458	1.4713	1.09839	1.47315	1.02504	0.76569	0.688085	0.555864	0.34891	0.190123	0.144032	0.094171	0.038046	0.038353
1985	1.35242	3.9848	0.693896	3.8561	1.24982	1.54572	0.728689	0.967968	1.26895	0.923629	1.20738	0.826375	0.612542	0.548764	0.443314	0.278264	0.151628	0.114869	0.075103	0.06093
1986	1.0992	1.19944	3.53379	0.615235	3.41703	1.10579	1.36189	0.635323	0.825019	1.04325	0.732119	0.934843	0.632846	0.467035	0.418407	0.338007	0.212163	0.115609	0.087582	0.103719
1987	1.56509	0.974862	1.06369	3.13324	0.545203	3.02358	0.974569	1.1883	0.542455	0.680566	0.831069	0.57029	0.720592	0.485765	0.358491	0.321165	0.25945	0.162854	0.08874	0.146841
1988	2.22405	1.38806	0.864539	0.943149	2.7768	0.482525	2.66626	0.851563	1.01799	0.450326	0.547273	0.654769	0.445024	0.560162	0.377617	0.278678	0.249662	0.201687	0.126597	0.183132
1989	2.18683	1.97246	1.23094	0.766499	0.835656	2.45596	0.424747	2.31906	0.721763	0.828065	0.35137	0.415742	0.491205	0.332187	0.418133	0.281872	0.208019	0.18636	0.150549	0.231197
1990	0.962649	1.93948	1.74926	1.09147	0.679339	0.739702	2.16664	0.371546	1.99177	0.60211	0.670712	0.27926	0.3275	0.385576	0.260754	0.328217	0.221258	0.163287	0.146285	0.299655
1991	0.929919	0.853779	1.72009	1.55125	0.967694	0.601918	0.654284	1.90823	0.324209	1.71255	0.510023	0.562705	0.233238	0.273037	0.321455	0.21739	0.273635	0.184463	0.136132	0.371781
1992	2.87267	0.824749	0.757194	1.52536	1.37528	0.857314	0.532247	0.575788	1.66202	0.277774	1.44305	0.425188	0.466762	0.193083	0.22603	0.266112	0.179964	0.226525	0.152705	0.420469
1993	1.59246	2.54775	0.731424	0.671412	1.35198	1.21755	0.756624	0.466065	0.495722	1.39289	0.22653	1.15639	0.337939	0.369766	0.152959	0.17906	0.210813	0.142567	0.179452	0.454066
1994	1.49119	1.41236	2.25952	0.648611	0.595224	1.19763	1.07628	0.665309	0.405165	0.423197	1.16744	0.187637	0.952559	0.277758	0.303918	0.12572	0.147173	0.173271	0.117178	0.5207
1995	1.11324	1.32253	1.25255	2.00357	0.574909	0.527012	1.05727	0.943158	0.573798	0.340691	0.346834	0.941138	0.150099	0.759647	0.221507	0.242369	0.100259	0.117367	0.13818	0.508695
1996	1.85916	0.987332	1.17289	1.11069	1.776	0.509103	0.465443	0.927495	0.815453	0.484778	0.28118	0.281981	0.759789	0.120836	0.611547	0.178322	0.195116	0.080713	0.094486	0.520761
1997	1.2918	1.64888	0.875615	1.04003	0.984483	1.5725	0.449458	0.407914	0.800106	0.685991	0.397563	0.226853	0.225762	0.606448	0.096449	0.488124	0.142333	0.155738	0.064423	0.491078
1998	1.41698	1.14567	1.46225	0.776344	0.921574	0.870941	1.3851	0.391584	0.347087	0.655683	0.541167	0.306054	0.172647	0.171032	0.459431	0.073067	0.369792	0.107828	0.117984	0.420835
1999	1.68687	1.25672	1.01605	1.29664	0.688172	0.816108	0.769247	1.21531	0.338709	0.29348	0.54181	0.440625	0.247473	0.139216	0.137913	0.370467	0.058919	0.298185	0.086948	0.434482
2000	1.89764	1.4961	1.11455	0.901029	1.14958	0.609713	0.721765	0.677249	1.05956	0.29075	0.247993	0.45323	0.366845	0.205646	0.115686	0.114604	0.307852	0.04896	0.247787	0.4333
2001	1.93362	1.68302	1.32684	0.988349	0.798759	1.01824	0.538835	0.634244	0.587864	0.901938	0.242653	0.204357	0.371265	0.299789	0.168056	0.09454	0.093655	0.251579	0.040011	0.55659

Table 3.11--Estimated age 5 recruitment (millions) from the 2000 and 2001 assessments.

Year class	2000 \ssessmer	2001 \ssessmen
59	1,133	1,129
60	654	651
61	1,143	1,129
62	569	556
63	543	527
64	769	740
65	927	882
66	1,548	1,454
67	1,697	1,573
68	1,670	1,534
69	2,321	2,113
70	2,856	2,575
71	2,787	2,491
72	2,496	2,217
73	2,739	2,422
74	3,292	2,894
75	2,103	1,837
76	2,463	2,138
77	1,638	1,411
78	1,091	932
79	2,067	1,746
80	1,499	1,250
81	4,156	3,417
82	609	545
83	3,444	2,777
84	972	836
85	829	679
86	1,201	968
87	1,790	1,375
88	1,819	1,352
89	789	595
90	826	575
91	2,607	1,776
92	1,371	984
93	1,469	922
94	1,083	688
95	1,397	1,150
96		799

Table 3.12--Projections of yellowfin sole female spawing biomass (1,000s t), catch (1,000s t) and full selection fishing mortality rate for seven future harvest scenarios.

Scenarios 1 and 2
Maximum ABC harvest permissible

Year	Female spawning	catch	F
2001	447.497	51.104	0.05
2002	445.656	114.924	0.11
2003	428.297	109.782	0.11
2004	408.162	104.581	0.11
2005	389.382	99.414	0.11
2006	374.457	92.384	0.11
2007	364.368	88.320	0.11
2008	359.018	86.929	0.10
2009	358.096	87.548	0.10
2010	361.167	89.760	0.11
2011	366.946	92.877	0.11
2012	372.180	95.181	0.11
2013	377.040	96.894	0.11
2014	381.151	98.159	0.11

Scenario 3
1/2 Maximum ABC harvest permissible

Year	Female spawning	catch	F
2001	447.497	51.103	0.05
2002	453.668	58.907	0.06
2003	458.976	59.060	0.06
2004	459.116	58.809	0.06
2005	457.711	58.555	0.06
2006	456.781	58.493	0.06
2007	457.048	58.822	0.06
2008	459.332	59.638	0.06
2009	464.200	60.753	0.06
2010	472.482	62.114	0.06
2011	484.012	63.655	0.06
2012	494.760	64.973	0.06
2013	505.184	66.177	0.06
2014	514.627	67.242	0.06

Scenario 4
Harvest at average F over the past 5 years

Year	Female spawning	catch	F
2001	447.497	51.102	0.05
2002	447.309	103.519	0.10
2003	434.490	99.883	0.10
2004	418.234	96.022	0.10
2005	402.529	92.669	0.10
2006	389.346	90.107	0.10
2007	379.238	88.637	0.10
2008	372.851	88.351	0.10
2009	370.485	88.862	0.10
2010	372.271	89.941	0.10
2011	377.359	91.365	0.10
2012	382.509	92.580	0.10
2013	387.755	93.694	0.10
2014	392.526	94.668	0.10

Scenario 5
No fishing

Year	Female spawning	catch	F
2001	447.497	0	0
2002	461.828	0	0
2003	491.936	0	0
2004	516.804	0	0
2005	539.215	0	0
2006	560.825	0	0
2007	582.174	0	0
2008	603.918	0	0
2009	626.561	0	0
2010	651.759	0	0
2011	680.436	0	0
2012	706.868	0	0
2013	732.252	0	0
2014	755.693	0	0

Scenario 6
Determination of whether yellowfin sole are currently overfished B35=343.145

Year	Female spawning	catch	F
2001	447.497	51.104	0.05
2002	442.520	136.359	0.14
2003	416.733	127.796	0.14
2004	389.759	118.932	0.14
2005	366.643	105.623	0.13
2006	350.133	96.928	0.12
2007	339.329	92.052	0.12
2008	333.787	90.417	0.12
2009	332.940	91.143	0.12
2010	336.063	93.627	0.12
2011	341.658	97.131	0.12
2012	346.616	100.020	0.12
2013	350.942	102.308	0.12
2014	354.311	103.966	0.12

Scenario 7
Determination of whether the stock is approaching an overfished condition B35=343.145

Year	Female spawning	catch	F
2001	447.497	51.103	0.05
2002	445.656	114.924	0.11
2003	428.297	109.782	0.11
2004	405.283	124.088	0.14
2005	379.344	112.803	0.13
2006	359.582	101.961	0.13
2007	346.241	95.592	0.12
2008	338.742	92.920	0.12
2009	336.410	92.941	0.12
2010	338.431	94.968	0.12
2011	343.253	98.057	0.12
2012	347.614	100.525	0.12
2013	351.551	102.561	0.12
2014	354.716	104.101	0.12

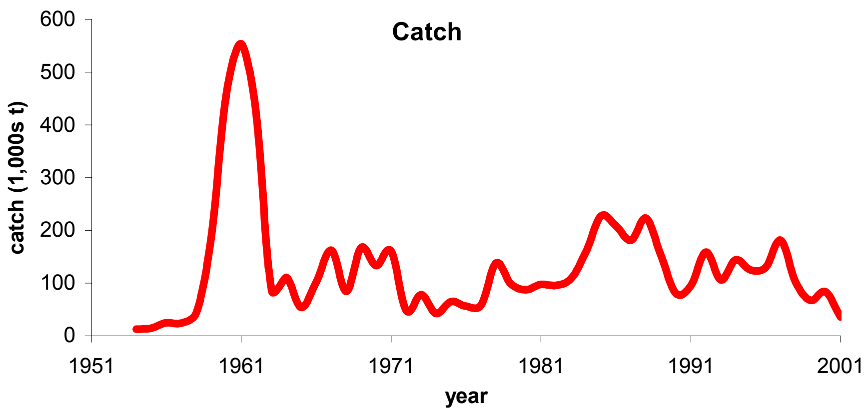

Figure 3.1-Catch of yellowfin sole (t) 1955-September 15, 2001.

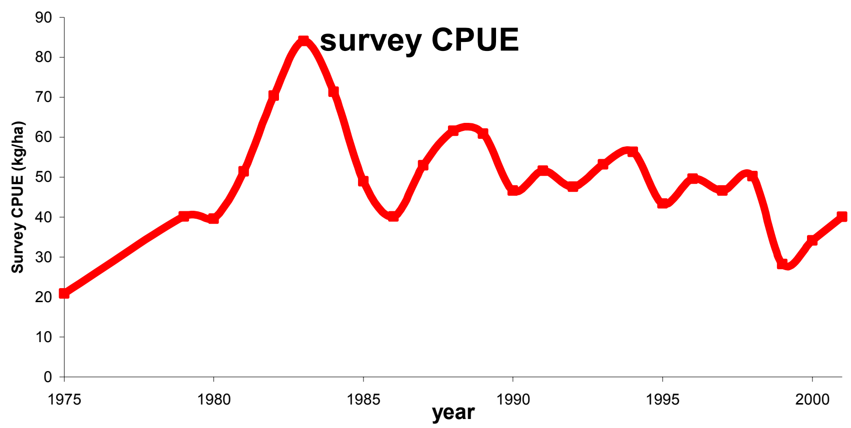

Figure 3.2--Yellowfin sole CPUE (kg/ha) from the annual Bering Sea shelf trawl surveys, 1975 and 1979-2001.

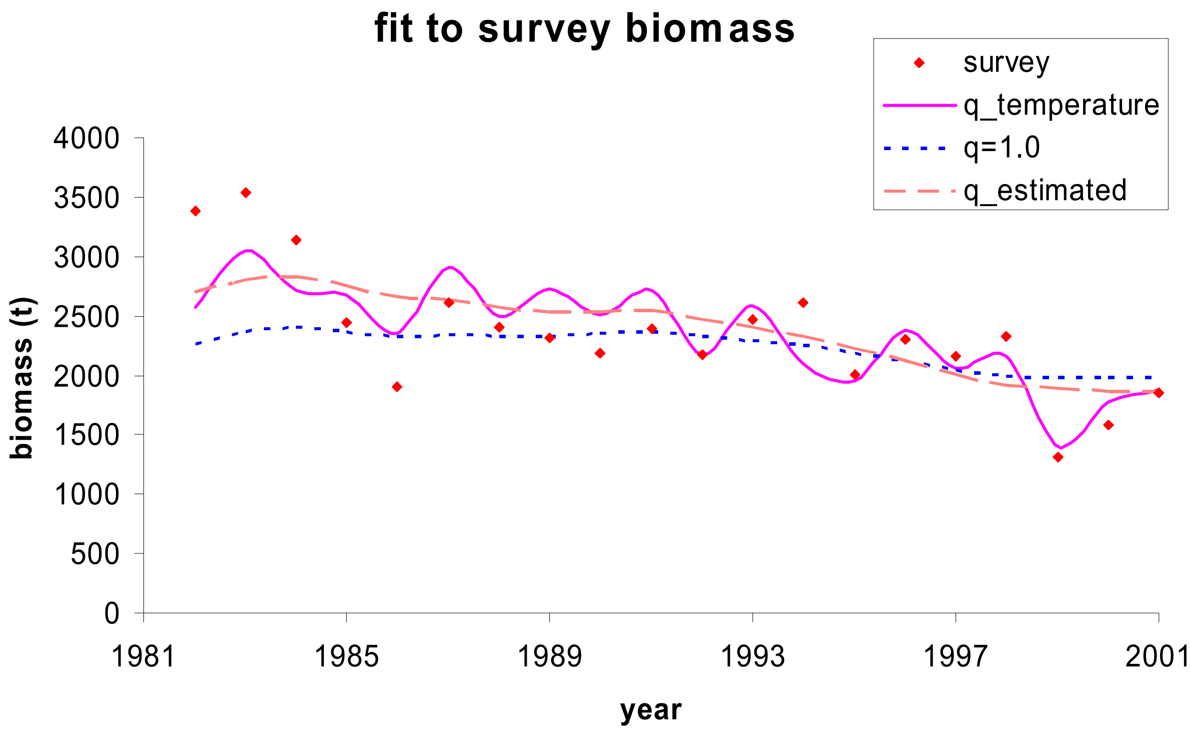

Figure 3.5--Fit of Model A (q=1.0), Model B (q is estimated as a single value for all years) and Model C (annual estimate of q which varies with bottom water temperature) to the trawl survey point estimates of biomass (t).

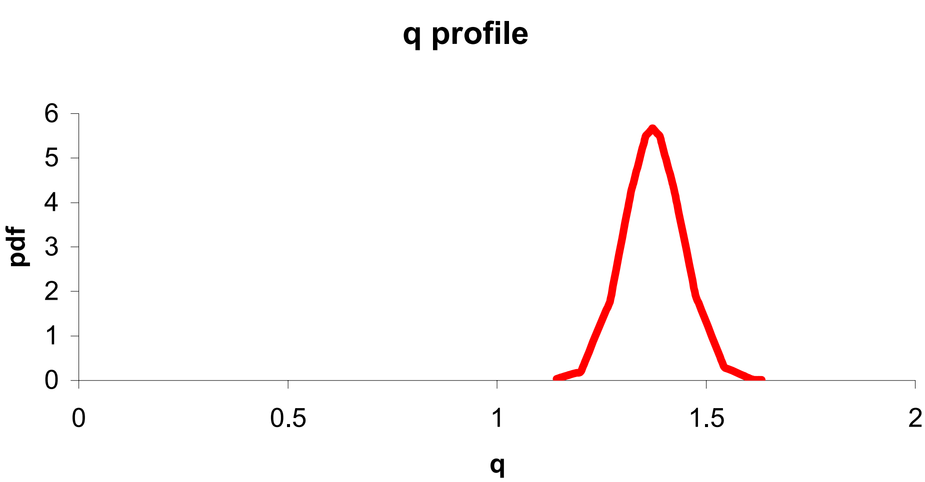

Figure 3.6--Likelihood profile of survey catchability (q).

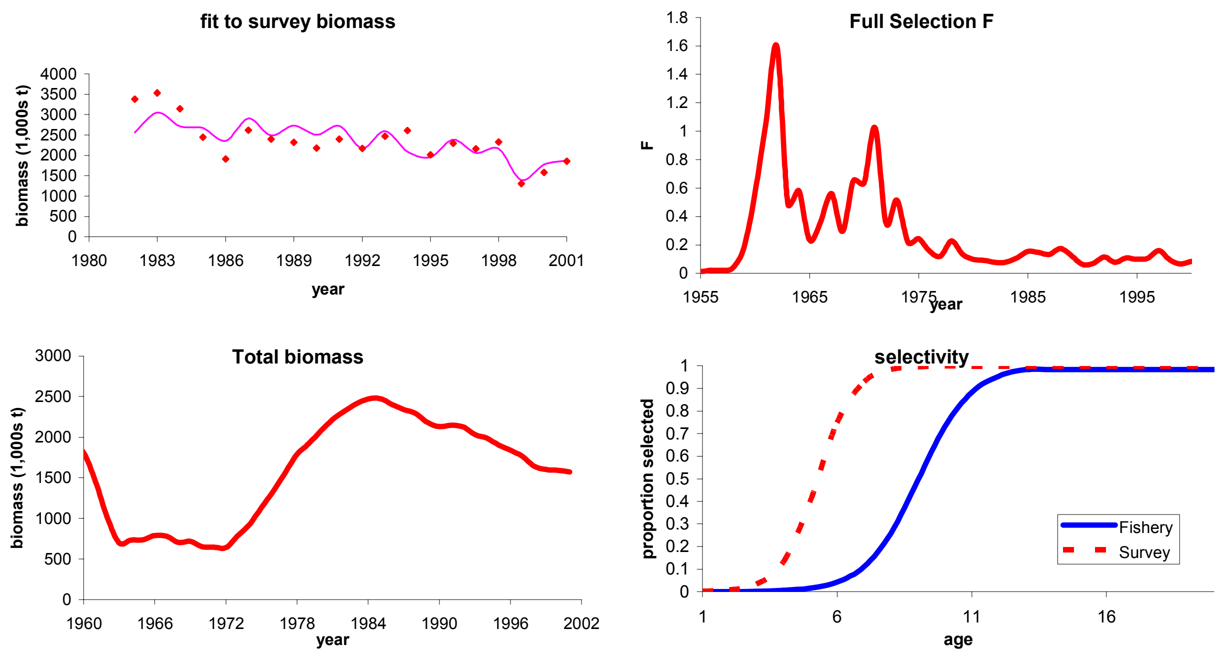

Figure 3.7--Model fit to the survey biomass estimates (top left panel), model estimate of the mean annual fishing mortality rate throughout the time-series (top right panel), model estimate of total biomass (bottom left panel) and the model estimate of fishery and survey selectivity (bottom right panel).

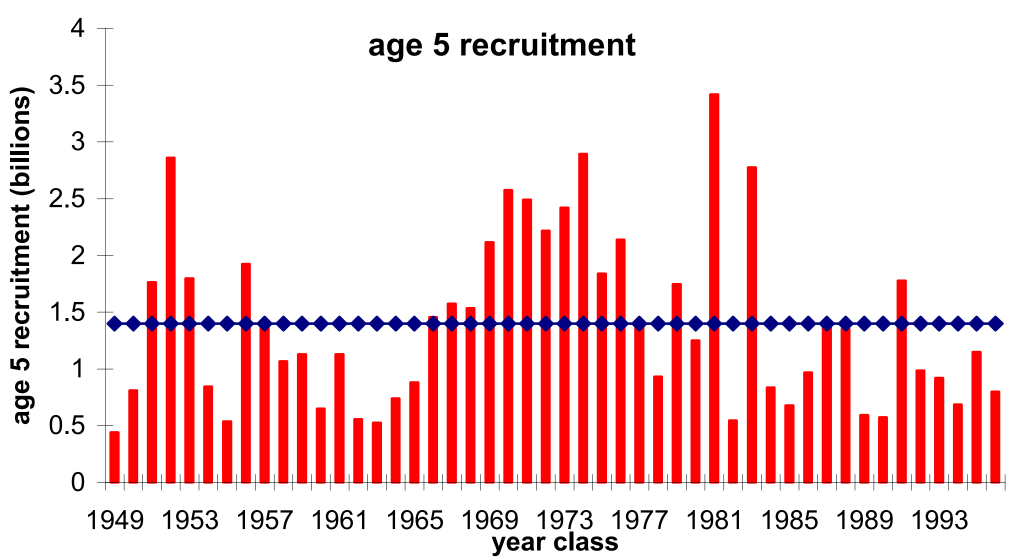

Figure 3.8--Year class strength of age 5 yellowfin sole estimated by the stock assessment model. The dotted line is the average of the estimates from 48 years of recruitment.

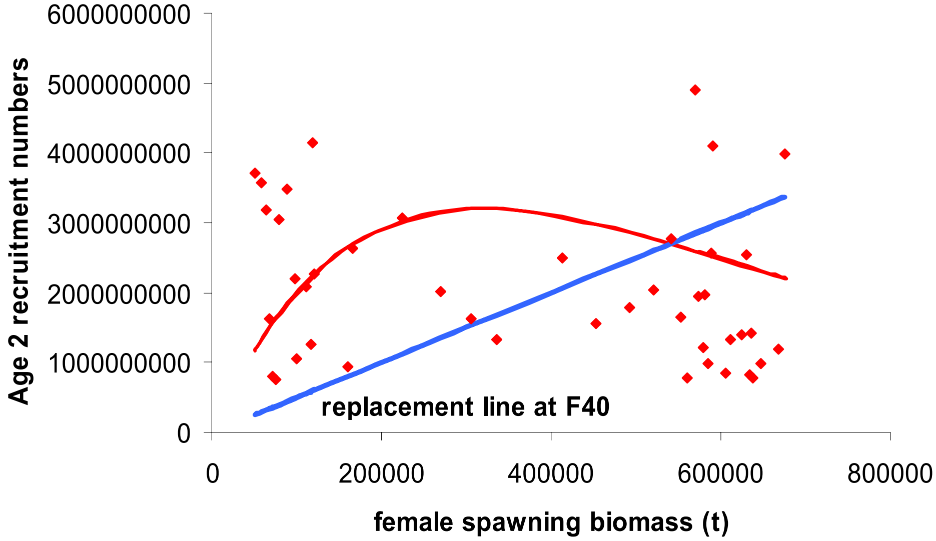

Figure 3.9--Ricker curve fit to yellowfin sole female spawning biomass-age 2 recruitment numbers.

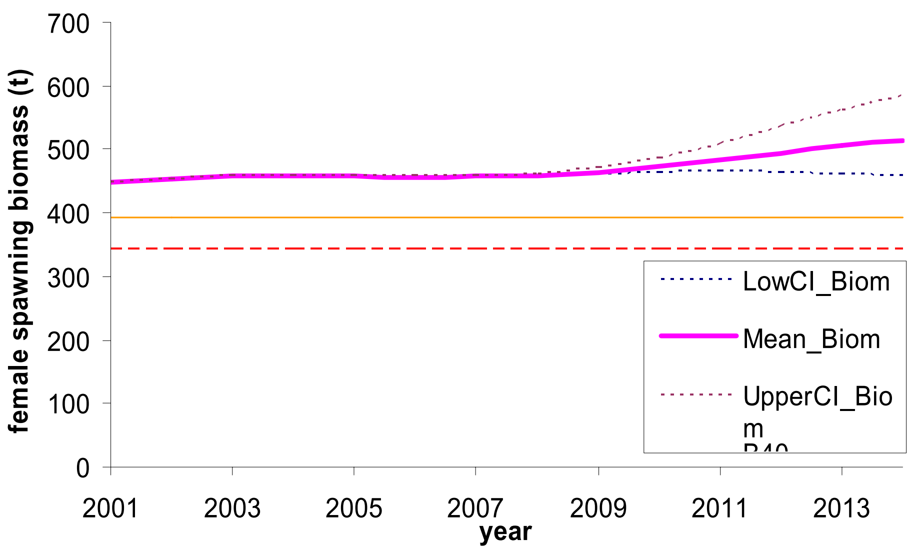

Figure 3.11--Projection of yellowfin sole female spawning biomass (t) at one half of maximum ABC through 2014 with B40 and B35 levels indicated.